

CHARGING AHEAD: LESSONS FROM THE EUROPEAN UNION AND CHINA FOR UNITED STATES FEDERAL REGULATION OF ELECTRIC VEHICLE BATTERY WASTE

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INTRODUCTION

“If there is one country that bears the most responsibility for the lack of progress on international environmental issues, it is the United States.”—
Gus Speth, *Red Sky at Dawn*¹

The late nineteenth century saw one of the most monumental battles between three of the greatest inventors of their time: Thomas Edison, Nikola Tesla, and George Westinghouse. Each sought to determine whether the United States’ standard electrical system would be direct current (“DC”) or alternating current (“AC”).² This battle was dubbed the “War of the Currents.”³ Driven by huge leaps in technological innovation, this battle “shape[d] the future of electric power distribution,”⁴ but, more importantly, these technological leaps also solidified an era of environmental challenges that would soon become apparent in the following century.

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1. Steven F. Hayward, *The United States and the Environment: Laggard or Leader?*, AM. ENTER. INST. 1, 1 (Feb. 21, 2008), https://www.aei.org/wp-content/uploads/2011/10/20080221_22749EPO01Hayward_g.pdf?x85095 [<https://perma.cc/2HWC-8K4Z>].

2. Elizabeth Nix, *How Edison, Tesla and Westinghouse Battled to Electrify America*, HIST. (Sep. 5, 2025), <https://www.history.com/news/what-was-the-war-of-the-currents> [<https://perma.cc/J8K2-XG7M>] (explaining that Edison supported the adoption of DC current, which is when “electrical current flows steadily in one direction,” while Tesla and Westinghouse supported AC current resulting in “the current’s flow constantly alternat[ing]”).

3. The “War of the Currents” was a battle deciding whether the DC current or AC current was the most efficient method for electricity distribution. Edison’s invention of the first electrical power station was a revolutionary contribution to the DC current system, which supplied electricity to consumers who lived within a square mile of the DC system. The DC current, however, was quite limited in that electricity could only be supplied within a one-to-two-mile radius because of the large amount of electricity lost during transmission from long distances. Tesla’s AC system marked a significant turning point and was able to overcome what Edison’s could not: the ability to transmit electricity over long distances through efficient power transmission. A monumental demonstration at the Chicago World’s Fair, where twenty-seven million people witnessed AC power lighting the fair, propelled the AC system forward and marked the end of the “War of the Currents.” Arlen Olsen, *The War of the Currents*, SCHMEISER OLSEN & WATTS LLP (Mar. 25, 2024), <https://iplawusa.com/the-war-of-the-currents-a-battle-of-patents-and-power/> [<https://perma.cc/T5UF-UWAF>].

4. *Id.*

While Tesla's AC system—through the eventual trust and support of Westinghouse and the public—became the standard electrical system, it was Edison's invention of the first electrical power station that gave rise to coal-fired power plants.⁵ In 1882, Edison built the Holborn Viaduct, the first coal-fired power station to open in the world.⁶ Coal dominated the energy sector; this increased usage of coal became responsible not only for large increases in greenhouse gas emissions ("GHG") but also brought upon the world the infamous "wicked problem": climate change.⁷

Edison's legacy, however, cannot solely be attributed to environmental harm. In the early 1900s, Edison invented the alkaline storage battery, which eventually evolved into the rechargeable battery technologies seen today.⁸ Edison's invention of the alkaline battery helped pave the way for lithium-ion batteries ("LIBs"), a battery crucial for the rise of electric vehicles ("EVs").⁹ These LIB-powered vehicles help reduce carbon emissions from the transportation sector.¹⁰ Edison's invention of the electric power system and alkaline storage battery highlights an important message: technological progress comes with a vital responsibility to protect the environment.

Just as Edison's electrical power station led to inadvertent and unforeseen environmental problems, the current push to adopt EVs in today's transportation market is presenting a new environmental dilemma: managing the disposal of LIBs at the end of their life cycle.¹¹ While EVs are arguably the answer to reducing carbon emissions from the transportation sector, once a life-cycle analysis is applied to these vehicles, one may question whether EVs are truly the answer to bringing the United States towards a low-carbon future.¹²

5. *Id.*; Clean Growth Fund (@Jonathan Tudor), *Thomas Edison: The Father of Coal-Fired Power and the Unintended Environmental Consequences: A Mixed Legacy?*, LINKEDIN (Oct. 1, 2024), <https://www.linkedin.com/pulse/thomas-edison-father-coal-fired-power-unintended-environmental-kjuge/> [https://perma.cc/9J5T-FUE5].

6. Clean Growth Fund, *supra* note 5.

7. *Id.*; The term "wicked problem" refers to an issue that "presents great scientific and economic complexity, some very deep uncertainties, profound ethical issues, and even lack of agreement on what the problem is." *A Wicked Problem: Controlling Global Climate Change*, WORLD BANK GRP. (Sep. 30, 2014), <https://www.worldbank.org/en/news/feature/2014/09/30/a-wicked-problem-controlling-global-climate-change> [https://perma.cc/8VSY-9H7T].

8. Clean Growth Fund, *supra* note 5.

9. *Id.*

10. *Id.*

11. See Ian Morse, *A Dead Battery Dilemma*, SCI. (May 20, 2021, 12:44 PM), <https://www.science.org/content/article/millions-electric-cars-are-coming-what-happens-all-dead-batteries> [https://perma.cc/2ASF-TMAS].

12. A life cycle analysis "is a tool that scientists and policymakers use to assess the environmental impacts of a product, process, or activity throughout its life cycle—from the extraction of raw materials to its processing, transport, use, and disposal." Two common types of life cycle analyses include the attributional life cycle analysis and the consequential life cycle analysis. An attributional life cycle analysis "seeks to determine what portion of total human environmental impact can be traced to a particular product," whereas a consequential life cycle

Specifically, the source of electricity powering the EVs and the battery waste disposal issues may lead some to question the zero-carbon promises of these vehicles.¹³ Without a standardized system for proper disposal and recycling of LIBs, the materials in the batteries will inevitably reach landfills and result in environmental harm through the release of hazardous materials.¹⁴

With the invention of rechargeable batteries, the next crucial step in the evolution of battery technology will be to address the environmental concerns of disposal and recycling. The goal now is to implement proper practices, so history does not repeat itself, where one problem is solved only to create another. Implementing proper disposal and recycling practices has become increasingly urgent as EVs gain popularity across the world and in the United States.¹⁵ In 2023, EV sales in the United States increased by fifty percent in one year, with over 1.4 million units sold.¹⁶ Further, EV sales approached fourteen million in 2023, with ninety-five percent of these sales occurring in the United States, the European Union (“EU”), and China.¹⁷ The retirement of EV batteries is expected to grow during the second half of the 2030s due to the increasing sales of EVs.¹⁸ These EV sales will lead to an increasing number of batteries that need to be disposed of: “the cumulative burden of electric-vehicle waste is substantial given the growth trajectory of the electric-vehicle market.”¹⁹

This growth in EV sales is not merely a market trend. The top EV sellers have pushed for the adoption of these vehicles to decarbonize the transportation sector and address climate change.²⁰ Importantly, EVs are viewed as the better

analysis “asks how total human environmental impact changes as a result of producing and using that product.” Alexandra B. Klass & Andrew Heiring, *Life Cycle Analysis and Transportation Energy*, 82 BROOK. L. REV. 485, 486-488 (2017).

13. *Id.* at 486.

14. Jay N. Meegoda, Sarvagna Malladi & Isabel C. Zayas, *End-of-Life Management of Electric Vehicle Lithium-Ion Batteries in the United States*, 4 CLEAN TECHS. 1162, 1162 (Nov. 14, 2022), <https://doi.org/10.3390/cleantechnol4040071> [<https://perma.cc/XRW7-G39G>].

15. See *Global EV Outlook 2024*, IEA 11, 24 (2024), <https://www.iea.org/reports/global-ev-outlook-2024> [<https://perma.cc/AM4Z-AZCK>].

16. *Statement by U.S. Energy Secretary Jennifer M. Granholm on 2023 EV Sales*, DEP’T OF ENERGY (Jan. 5, 2024), <https://www.energy.gov/articles/statement-us-energy-secretary-jennifer-m-granholm-2023-ev-sales> [<https://perma.cc/JX8W-JRFJ>].

17. *Global EV Outlook 2024*, *supra* note 15, at 17.

18. *Id.* at 14.

19. Gavin Harper et al., *Recycling Lithium-Ion Batteries from Electric Vehicles*, 575 NATURE 75, 75 (2019).

20. In the United States, the push for decarbonization policies in the transportation sector has been largely affected by presidential administrations, especially in the past decade. For example, the 2017-21 Trump Administration rolled back over one hundred environmental policies, many of which weakened the Obama Administration’s policies, such as mitigating carbon emissions from cars and trucks. The 2021-25 Biden Administration then reversed some of the rollbacks of the Trump Administration. While the United States has made climate progress, the back-and-forth actions of successive administrations have made it difficult to maintain a consistent push for climate-friendly initiatives. See, Nadja Popovich et al., *The Trump Administration Rolled Back More Than 100 Environmental Rules. Here’s the Full List.*, N.Y. TIMES (Jan. 20, 2021),

alternative to gas- and diesel-powered automobiles due to their mitigating effects of air pollution and GHG emissions.²¹ Moreover, the United States has implemented specific climate targets such as “cut[ting] overall [United States] greenhouse gas emissions 50-52 percent by 2030 relative to 2005 levels, fifty percent electric vehicle sales share by 2030, one hundred percent carbon pollution-free electricity by 2035, and a net-zero emissions economy by 2050.”²² By 2030, the EU seeks to cut GHGs by at least fifty-five percent compared to 1990 levels²³ and aims to achieve net-zero GHG emissions by 2050.²⁴ The EU also seeks to achieve twenty-three percent of global EV sales by 2030.²⁵ In comparison, China seeks to achieve carbon neutrality before 2060 and increase its non-fossil fuel share of primary energy consumption to about twenty-five percent by 2030.²⁶ Despite the United States’ climate goals and its status as a top seller of EVs, the United States continues to lag behind the EU and China in LIB disposal and recycling regulations. This note argues that while the United States has been slow to implement federal LIB waste programs, adopting similar frameworks to those in the EU and China and amending the Resource Conservation and Recovery Act (“RCRA”) could improve the regulatory landscape of LIB recycling and disposal in the United States.

Part I of this note examines the nature of LIBs, the challenges related to their disposal and recycling at the end of their life, and the need for proper disposal and recycling practices. Part II discusses a broad overview of the legal regulatory frameworks for managing the disposal and recycling methods of EV LIBs in the EU, China, and the United States, particularly focusing on RCRA. Part III discusses extended producer responsibility (“EPR”) broadly and considers the shortcomings and successes of the EU and China’s EPR frameworks. Part III also compares China and the EU’s frameworks for EV

<https://www.nytimes.com/interactive/2020/climate/trump-environment-rollback-list.html> [<https://perma.cc/HA28-72WA>]; Oliver Milman & Alvin Chang, *How Biden is reversing Trump’s assault on the environment*, THE GUARDIAN (Feb. 2, 2021), <https://www.theguardian.com/us-news/2021/feb/02/biden-trump-environment-climate-crisis> [<https://perma.cc/5HY8-WRQ8>].

21. David Keith & Aaron Krol, *Electric Vehicles*, MIT CLIMATE PORTAL (July 24, 2023), <https://climate.mit.edu/explainers/electric-vehicles> [<https://perma.cc/2GGA-L728>].

22. *The Climate Crisis: Working Together For Future Generations*, U.S. DEP’T OF STATE, <https://www.state.gov/policy-issues/climate-crisis/> [<https://perma.cc/KE7H-PJG8>] (last visited Oct. 30, 2024).

23. *2030 Climate Targets*, EUR. COMM’N, https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2030-climate-targets_en [<https://perma.cc/M6JB-LEZH>] (last visited Oct. 30, 2024).

24. *2050 Long-Term Strategy*, EUR. COMM’N, https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en [<https://perma.cc/E8JT-N78D>] (last visited Oct. 30, 2024).

25. Lauren Fricke, *The Long-Term Problem with Electric Vehicle Batteries: A Policy Recommendation to Encourage Advancement for Scalable Recycling Practices*, 12 SEATTLE J. TECH., ENV’T & INNOVATION L. 27, 39 (2022).

26. MINISTRY OF ECOLOGY & ENV’T OF CHINA, CHINA’S POLICIES AND ACTIONS FOR ADDRESSING CLIMATE CHANGE 5 (2022), <https://english.mee.gov.cn/Resources/Reports/reports/202211/P020221110605466439270.pdf> [<https://perma.cc/MLQ2-RVLQ>].

battery waste regulation to the United States' current framework, while also examining the benefits and limitations of implementing an EPR approach. Lastly, Part IV includes recommendations the United States should consider, drawing from successful practices in the EU and China, to implement a federal EV battery waste management system and strengthen its regulatory landscape.

I. LITHIUM-ION BATTERIES

A. Structure and Components

While Edison's alkaline storage batteries helped pave the way for rechargeable battery technologies, it was not until 1979 that John B. Goodenough created LIBs.²⁷ LIBs are a popular choice of battery in both electronic devices and EVs for their rechargeable and portable systems.²⁸

At the end of its life, EV batteries are generally broken down, and their materials are either recycled individually or used to make a different product than their current form.²⁹ The complexity of LIBs and the materials contained within them emphasizes the challenges in ensuring proper disposal and recycling. To illustrate, current LIBs consist of multiple cells assembled into modules and enclosed within a large pack.³⁰ The battery consists of "an anode, cathode, separator, electrolyte, and two current collectors (positive and negative)."³¹ The lithium is stored in the anode and cathode, where the electrolyte then transports positively charged lithium ions between the anode and the cathode through a separator.³² The cathode material can vary and contain different metal oxides, including lithium cobalt oxide, lithium nickel, or lithium-ion phosphate.³³ As the lithium ions move, free electrons are created in the anode, creating "a charge at the positive current collector," where the electrical current then follows from the current collector to the negative current collector.³⁴ Other parts of the battery are made of additional resources and recyclable materials. The anodes contain materials such as graphite, PVDF, and copper foil; separators contain plastic films generally containing polyethylene or polypropylene; and the electrolyte is usually made of "lithium

27. Harrison Lebov, *A Darker Shade of Green: Hazards Associated with Lithium-Ion Batteries*, 17 J. HIGH TECH. L. 78, 81 (2016).

28. Lauren Neuhaus, *The Electrifying Problem of Used Lithium Ion Batteries: Recommendations for Recycling and Disposal*, 42 ENVIRONS ENV'T L. & POL'Y J. 67, 70 (2018).

29. Fricke, *supra* note 25, at 32.

30. *Id.* at 31.

31. *How Lithium-ion Batteries Work*, U.S. DEP'T OF ENERGY: ENERGY SAVER (Feb. 28, 2023), <https://www.energy.gov/energysaver/articles/how-lithium-ion-batteries-work> [<https://perma.cc/99UQ-9675>].

32. *Id.*

33. Fricke, *supra* note 25, at 31.

34. *How Lithium-ion Batteries Work*, *supra* note 31.

hexafluorophosphate dissolved in ethylene carbonate and dimethyl carbonate.”³⁵

B. Environmental and Social Impacts of LIBs

Manufacturers of LIBs often vary in the design of the battery, including its configuration, size, shape of the cells, modules, packs, and chemical compositions.³⁶ This design inconsistency makes LIBs from EVs difficult to recycle, since the materials’ diverse chemical compositions may require different recycling conditions.³⁷ Moreover, because battery designs vary by manufacturer, the compositions of batteries may never standardize.³⁸ Accordingly, the environmental impacts of a LIB depend largely on the design of the battery.³⁹

The environmental impact of LIBs must be considered when implementing waste management regulations. If LIBs become disposed of at the end of their life, the batteries become electronic waste, also known as e-waste.⁴⁰ The World Health Organization has identified e-waste as one of the fastest-growing types of solid waste globally.⁴¹ Furthermore, since e-waste contains toxic materials, if not properly recycled, it can create toxic chemicals that harm not only the environment but also human health.⁴² Specifically, hazardous materials in the batteries can leak from the battery casings, contaminating groundwater and soil.⁴³ The waste can also end up in landfills and cause large fires due to its mixture with combustible waste.⁴⁴ Because LIBs are chemically and electrically hazardous, the United States Department of Transportation regulates the

35. Fricke, *supra* note 25, at 31. PVDF is a synthetic resin, also known as polyvinylidene fluoride. *Polyvinylidene Fluoride*, BRITANNICA, <https://www.britannica.com/science/polyvinylidene-fluoride> [<https://perma.cc/CJ5E-Y53S>] (last visited Mar. 4, 2025).

36. Fricke, *supra* note 25, at 31.

37. Liz Harland, *The Dirty Effects of Clean Energy Technology: Supportive Regulations to Promote Recycling of Lithium Ion Vehicle Batteries*, 7 SAN DIEGO J. CLIMATE & ENERGY L. 167, 175-176 (2016) (arguing that “[s]tandardization of batteries, materials, and cell design would make recycling easier and more cost-effective.”).

38. Neuhaus, *supra* note 28, at 70, 74.

39. *Id.* at 71.

40. *Environmental Impacts of Lithium-ion Batteries*, UL RSCH. INST. (Mar. 16, 2022), <https://ul.org/research/electrochemical-safety/getting-started-electrochemical-safety/environmental-impacts> [<https://perma.cc/5NWJ-YT2J>].

41. *Electronic Waste (E-waste)*, WORLD HEALTH ORG. (Oct. 1, 2024), [https://www.who.int/news-room/fact-sheets/detail/electronic-waste-\(e-waste\)](https://www.who.int/news-room/fact-sheets/detail/electronic-waste-(e-waste)) [<https://perma.cc/4KZG-EGH5>].

42. *Id.* at 1-4. Children and pregnant women are particularly vulnerable to e-waste’s hazardous effects. Children can become exposed to toxic pollutants from the hazardous waste through waste picking and scavenging for parts, and fetuses exposed to the toxic chemicals may experience a disruption in the development of the central nervous system. Moreover, exposure can harm the structural development and proper functioning of the lungs.

43. Fricke, *supra* note 25, at 35.

44. *Environmental Impacts of Lithium-ion Batteries*, *supra* note 40.

movement of these batteries under the Hazardous Materials Regulations, 49 C.F.R., Parts 171-180.⁴⁵

In addition to harmful battery leakage, there are issues with the mining extraction process used to gather minerals to make the LIBs.⁴⁶ Corporations engage in a “race to the bottom” to make cheap investments in minerals from nations that have an abundance of such resources; however, these mineral-rich nations often engage in harmful practices that allow minerals to be extracted quickly and cheaply.⁴⁷ To gain business from corporations, these nations ignore social and environmental factors, such as cheap child labor, that would otherwise impede quick and cheap extraction.⁴⁸ The extraction process also results in extensive water usage, which creates water scarcity and contamination risks.⁴⁹ The Salar de Atacama region in Chile has been especially impacted by the extraction process: lithium mining consumes sixty-five percent of the region’s water.⁵⁰ Local communities were forced to abandon their ancestral settlements due to groundwater depletion, contaminated soil, and environmental degradation.⁵¹

Cobalt, another mineral extracted for the creation of LIBs, also poses serious environmental risks during the extraction phase. Cobalt mines create sulfuric acid from the sulfur minerals mixing with air and water, a process known as acid mine drainage.⁵² Sulfuric acid itself harms the environment, particularly through its long-term toxicity to aquatic life and its ability to burn plants, birds, and other land animals exposed to its corrosive nature.⁵³

45. Heather D. Stewart, *Municipalities Could Provide Valuable Second-Life Uses of Electric Vehicle Li-Ion Batteries While Legislators and Manufacturers Refine Safe Recycling and Disposal Practices*, 12 BARRY U. ENV’T & EARTH L. J. 130, 147 (2022).

46. Elizabeth H. Rudolf, *Out of Sight, Out of Mind: Addressing the Unseen but Potentially Detrimental Issues of the Lithium-Ion Battery Supply Chain*, 96 TUL. L. REV. ONLINE 28, 39 (2022); Dylan Hays, *My Brother’s Keeper: A Framework for a Legal Obligation to Respect Human Rights in Global Supply Chains*, 88 GEO. WASH. L. REV. 454, 459 (2020).

47. *Id.*

48. *Id.*

49. *Id.* at 39-40.

50. *Id.* at 40 (illustrating how the lithium extraction process has impacted indigenous communities and writing that, “one indigenous protestor’s sign read, “[w]e don’t eat batteries They take the water, life is gone.”).

51. *Id.*

52. *Id.* at 41; *Acid Mine Drainage*, EARTHWORKS, <https://earthworks.org/issues/acid-mine-drainage/> [<https://perma.cc/ZMN9-B78P>] (last visited Nov. 18, 2024) (explaining that acid mine drainage is particularly harmful because it can persist long after mining activities have stopped. For hard rock surface mines, once acid mine drainage occurs at a large scale, it is not likely that the drainage can be stopped. Therefore, water treatment may be required for hundreds to thousands of years in many hard rock mines across the western United States).

53. *Sulfuric Acid*, AUSTRALIAN GOV’T: DEP’T OF CLIMATE CHANGE, ENERGY, THE ENV’T & WATER (Aug. 15, 2022), https://www.dceew.gov.au/environment/protection/npi/substances/fact-sheets/sulfuric-acid#toc_2 [<https://perma.cc/HET4-A4QQ>].

C. Environmental and Economic Benefits of EV Battery Recycling

While improper disposal of LIBs can cause significant environmental impacts, effective recycling programs for these batteries can present both environmental and economic benefits.

Effective recycling management offers several environmental benefits. First, improved recycling practices can reduce environmental damage caused by leaking toxins, as fewer hazardous materials would end up in landfills.⁵⁴ Second, recycling is expected to reduce dependence on extracting raw materials by allowing companies to repurpose recovered battery components.⁵⁵ Third, not only can dependence on raw materials be reduced, but this reduced dependence can help conserve rare earth metals and mitigate the environmental harm caused by mining activities.⁵⁶ This reduced dependency can help pave the way toward a circular economy, which is especially important in an era where demand for metals is expected to soar over the next several decades.⁵⁷ The circular economy aims to make a transition to renewable energy and materials while “decoupl[ing] economic activity from the consumption of finite resources.”⁵⁸ This requires tackling issues associated not only with a product’s end-of-life management, but also focusing on pre-disposal elements such as product design, manufacturing, delivery, and repair and refurbishing.⁵⁹

A key economic benefit of recycling LIBs is the ability to reuse the recovered materials in the production of new batteries, which will lower manufacturing costs and consumer purchase prices from the decreased manufacturing costs.⁶⁰ Furthermore, recycling can generate income and boost employment in local communities, as the high cost of transporting used batteries incentivizes companies to keep recycling operations local.⁶¹

D. Types of LIB Recycling

LIB recycling recovers a diverse group of materials, including lithium, cobalt, nickel, manganese, copper, aluminum, and steel.⁶² There are three main recycling practices used for LIBs, especially in the EU and China.⁶³ These

54. Fricke, *supra* note 25, at 35.

55. *Id.*

56. *Id.*

57. *Circular Economy and Extended Producer Responsibility*, GLOB. ALL. ON CIRCULAR ECON. & RES. EFFICIENCY 3, https://www.unido.org/sites/default/files/unido-publications/2023-11/GACERE_Circular%20Economy%20and%20Extended%20Producer%20Responsibility_webinar%20report.pdf [https://perma.cc/DX5T-H7MM] (last visited Feb. 16, 2025).

58. *Id.*

59. *Id.*

60. Fricke, *supra* note 25, at 36.

61. *Id.*

62. Luigi Toro et al., *A Systematic Review of Battery Recycling Technologies: Advances, Challenges, and Future Prospects*, 16 ENERGIES 1, 9 (Sep. 12, 2023).

63. Fricke, *supra* note 25, at 32.

practices are pyrometallurgical, hydrometallurgical, and direct recycling. Each recycling method is specifically designed to target particular materials from the LIBs.⁶⁴

Under pyrometallurgical recycling, the LIB is first dismantled at the modular level and then essentially smelted, where the electrolyte and plastic burn off, leaving behind valuable metals including copper, cobalt, nickel, and iron.⁶⁵ While this recycling method is effective in recovering the aforementioned resources, it is quite energy-inefficient and uneconomical, resulting in the loss of lithium, aluminum, and organic compounds during the process.⁶⁶ While seemingly lacking in this regard, the process can be used on any battery regardless of its chemical components; no pretreatment is required, and it can also be used on a larger scale.⁶⁷

The hydrometallurgical recycling method differs from the pyrometallurgical process because it involves acid leaching to dissolve metals such as lithium, cobalt, nickel, manganese, and copper.⁶⁸ This process can be tailored to dissolve specific metals based on their chemical composition⁶⁹ and is also recognized for its high metal recovery rates, energy efficiency, and zero emissions.⁷⁰ Some drawbacks include the process's high chemical reagent consumption and its generation of corrosive effluents.⁷¹

The last common method is direct recycling. Direct recycling seeks to recover and restore the functionality of LIB components rather than completely breaking the LIBs down into metals.⁷² This process involves removing the electrolyte using carbon dioxide under controlled conditions, breaking down the battery components, and separating them based on their properties, with some materials requiring further treatment before being reused.⁷³ Direct recycling attempts to reduce the number of processing steps and metal losses, allowing most battery components to be saved and reused.⁷⁴ The major drawback to direct

64. See Toro et al., *supra* note 62, at 9-13.

65. Fricke, *supra* note 25, at 33.

66. *Id.*

67. *Id.* Pretreatment is the first step of the recycling process for spent LIBs. It involves “battery sorting, deactivation, disassembling, classification, and separation of active cathode material from the current collector foils.” Once the battery goes through pretreatment, it then becomes subject to the pyrometallurgical or hydrometallurgical processes. Dawei Yu et al., *Pretreatment Options for the Recycling of Spent Lithium-Ion Batteries: A Comprehensive Review*, 173 MINERALS ENG'G (Nov. 1, 2021), <https://www.sciencedirect.com/science/article/abs/pii/S0892687521004477?via%3Dihub> [<https://doi.org/10.1016/j.mineng.2021.107218>].

68. Acid leaching is a process that uses “hot concentrated sulfuric acid” to dissolve metals. Toro et al., *supra* note 62, at 10.

69. Toro et al., *supra* note 62, at 10.

70. Fricke, *supra* note 25, at 34.

71. Toro et al., *supra* note 62, at 13.

72. *Id.*

73. Fricke, *supra* note 25, at 34.

74. *Id.*

recycling is that it requires complex pretreatment and separation of material in the battery.⁷⁵

E. Challenges to Recycling

There are two key issues that make LIB recycling difficult. First, recycling LIBs is economically burdensome. Due to the batteries' complex chemistry, recycling the materials is challenging, and the process is expensive because of the low recovery rates of the metals from the battery.⁷⁶ Furthermore, materials recovered from the batteries cannot cover the full recycling costs, including collecting, transporting, and sorting between battery chemistries, due to the LIB material's low market value.⁷⁷ Second, as previously mentioned, because manufacturers use different designs and chemical components for their batteries, the various recycling values make recycling more difficult.⁷⁸ The recycling processes differ depending on the type of chemical composition the manufacturer used for the LIB.⁷⁹ These challenges make it more difficult to achieve a uniform, efficient recycling program.⁸⁰ Effective uniform regulation of LIBs at the end of their life may help address these challenges, and by looking to China and the EU for guidance, the United States will be well on its way to promulgating effective regulatory laws for managing battery waste.

II. REGULATORY FRAMEWORKS FOR EV BATTERY WASTE MANAGEMENT: UNITED STATES, EUROPEAN UNION, AND CHINA

A. United States

1. Resource Conservation and Recovery Act ("RCRA")

The Resource Conservation and Recovery Act authorizes the United States Environmental Protection Agency ("EPA") to regulate hazardous waste from "cradle-to-grave," which includes its "generation, transportation, treatment, storage and disposal."⁸¹ RCRA regulates hazardous solid waste under Subtitle C, and non-hazardous solid waste under Subtitle D.⁸² To be considered "solid

75. *Id.*

76. Harland, *supra* note 37, at 175.

77. *Id.*

78. *Id.* at 175-76; *see supra* Section I.B.

79. Neuhaus, *supra* note 28, at 74.

80. *Id.*

81. *See* Resource Conservation and Recovery Act, 42 U.S.C. §§ 6901-6992k (1976); *Resource Conservation and Recovery Act (RCRA) Overview*, U.S. ENV'T PROT. AGENCY (Sep. 5, 2025), <https://www.epa.gov/rcra/resource-conservation-and-recovery-act-rcra-overview> [<https://perma.cc/8MM3-S7HG>].

82. Note that in order to be considered a "hazardous waste," the waste must first qualify as a "solid waste" under RCRA. *Resource Conservation and Recovery Act Overview*, *supra* note 81.

waste,” the waste must be discarded and can include any solids, liquids, and gases.⁸³ To be considered “hazardous waste,” the waste:

Because of its quantity, concentration, or physical, chemical, or infectious characteristics may—

(A) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or
(B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.⁸⁴

Furthermore, a hazardous waste will be regulated under RCRA if it is either specifically classified as a hazardous waste by the EPA, or if the waste “exhibits characteristics of ignitability, corrosivity, reactivity, or toxicity under prescribed testing conditions.”⁸⁵

Historically, there has been a lack of specific federal regulation guiding the recycling and proper disposal of spent LIBs from EVs.⁸⁶ In fact, there are currently no federal or state laws in force mandating EV battery recycling, except from New Jersey’s framework taking effect in 2027, discussed in Part III of this note.⁸⁷ Lithium itself is not classified as a hazardous material, and LIBs themselves are not listed as such either; nonetheless, because of the characteristics of some LIBs, including ignitability, corrosivity, reactivity, or toxicity, RCRA may apply.⁸⁸

To address the lack of regulation and guidance, the EPA’s Office of Resource Conservation and Recovery has issued new guidance in a memorandum clarifying how hazardous waste regulations for universal waste and recycling apply to LIBs under RCRA.⁸⁹ While the memorandum imposes no new federal regulatory requirements, it offers further direction for companies

83. *Id.*; See 40 C.F.R. § 261.2(a)(2)(i) (2025) for the EPA’s definition of “discarded material.”

84. 42 U.S.C. § 6903(5)(A)–(B) (1976); RCRA § 1004(5).

85. Neuhaus, *supra* note 28, at 73.

86. Stewart, *supra* note 45, at 148.

87. Samuel Boxerman & Drew Langan, *U.S. EPA Memo Offers Direction on Lithium Battery Recycling – Essential to the Future Supply Chain for Battery Electric Vehicles*, SIDLEY AUSTIN (Aug. 16, 2023), <https://environmentalenergybrief.sidley.com/2023/08/16/u-s-epa-memo-offers-direction-on-lithium-battery-recycling-essential-to-the-future-supply-chain-for-electric-vehicle-batteries/> [https://perma.cc/G8PW-8RJC].

88. Neuhaus, *supra* note 28, at 73–74; see *Defining Hazardous Waste: Listed, Characteristic and Mixed Radiological Wastes*, U.S. ENV’T PROT. AGENCY (Dec. 17, 2024), <https://www.epa.gov/hw/defining-hazardous-waste-listed-characteristic-and-mixed-radiological-wastes> [https://perma.cc/R8DH-2P99].

89. Memorandum from Carolyn Hoskinson, Dir., Off. of Res. Conservation and Recovery, to LCRD Division Directors, Region 1-10 (May 24, 2023), <https://rcrapublic.epa.gov/files/14957.pdf> [https://perma.cc/BEE8-SMMK].

involved in the generating, handling, storing, and recycling of spent LIBs.⁹⁰ The EPA made clear in its memo that LIBs are likely hazardous waste at the end of their life cycle and can first be regulated under the universal waste standards set forth in 40 C.F.R. Part 273 until the battery reaches a recycling or discard facility.⁹¹ Once the battery reaches its recycling or discard facility, the battery is no longer considered a universal waste and instead becomes a fully regulated hazardous waste.⁹² The EPA is currently working on a new proposal seeking to establish LIBs as a “new, distinct category of universal waste.”⁹³

To encourage the recycling and reusing of LIBs, EPA guidance provides that LIBs are not considered waste if they are being reused or repurposed.⁹⁴ If the batteries are determined to be non-reusable, they are considered solid waste subject to RCRA and regulated as universal waste until they reach the destination facility.⁹⁵ EPA guidance also provides that certain activities taken prior to the recycling phase, including removal of batteries from devices, sorting, and battery discharge, among other activities, are exempt from the RCRA hazardous waste permit requirement.⁹⁶ On the other hand, if a recycling facility is only holding batteries indefinitely, an RCRA permit may be needed, resulting in the loss of the benefit of exemption from needing an RCRA permit.⁹⁷ Further guidance from the EPA clarifies that generators are responsible for deciding whether spent LIBs should be classified as hazardous waste.⁹⁸ Classification of hazardous waste, however, could vary since the chemistry of batteries can differ.

90. Amanda G. Halter, Reza Zarghamee & Eric Moorman, *EPA Clarifies Requirements for Management of End-of-Life Lithium-Ion Batteries under RCRA*, PILLSBURY (July 10, 2023), <https://www.pillsburylaw.com/en/news-and-insights/epa-management-rcra-spent-lithium-ion-batteries.html> [<https://perma.cc/S6RX-FRTT>].

91. Hoskinson, *supra* note 89, at 1; The EPA’s universal waste program streamlines hazardous waste management and applies to five categories of universal waste: batteries, pesticides, mercury-containing equipment, lamps, and aerosol cans. Regulations under this program aim to accomplish three objectives: (1) promoting universal waste collection and recycling, (2) easing the regulatory burden on retail stores, generators, and transporters of the waste, and (3) decreasing the amount of waste sent to municipal solid waste landfills or combustors. *Universal Waste*, U.S. ENV’T PROT. AGENCY (Apr. 17, 2024), <https://www.epa.gov/hw/universal-waste> [<https://perma.cc/3KH6-324D>].

92. Hoskinson, *supra* note 89, at 9. Universal waste is generally regulated under more relaxed rules, unlike hazardous wastes, because universal waste is deemed to pose a lower immediate risk to human health and the environment. *Managing Hazardous Waste*, CAL. DEP’T OF TOXIC SUBSTANCES & CONTROL (Dec. 12, 2022), <https://dtsc.ca.gov/universalwaste/> [<https://perma.cc/5AWD-UXEZ>].

93. *Improving Recycling and Management of Renewable Energy Wastes: Universal Waste Regulations for Solar Panels and Lithium Batteries*, U.S. ENV’T PROT. AGENCY (Feb. 10, 2025), <https://www.epa.gov/hw/improving-recycling-and-management-renewable-energy-wastes-universal-waste-regulations-solar> [<https://perma.cc/4XC7-TYVX>].

94. Halter, Zarghamee & Moorman, *supra* note 90.

95. *Id.*

96. *Id.*

97. *Id.*

98. Boxerman & Langan, *supra* note 87.

While the EPA has issued this guidance for proper recycling, states have the authority to enact their own, more stringent RCRA programs.⁹⁹ Most states have not taken advantage of this authority, as they have not implemented separate disposal programs for spent LIBs.¹⁰⁰ The District of Columbia and California are outliers that have addressed battery regulation. The District of Columbia requires battery manufacturers to participate in a battery stewardship organization, and California has offered recycling recommendations through reports, but has not implemented direct legislation.¹⁰¹

Although the EPA has issued guidance on the recycling and disposal of LIBs under RCRA, the United States' approach is "less prescriptive" than the EU's approach.¹⁰² The EPA's memorandum recognizes the importance of having a plan in place to address battery recycling as EVs become increasingly popular, but unlike the EU's new battery regulations, discussed later, the United States falls drastically behind without these prescriptive battery requirements.¹⁰³ Without establishing specific regulatory frameworks for EV LIBs, the United States risks lagging behind in developing proper recycling and disposal practices, an increasingly critical issue as the nation's EV sales rise.¹⁰⁴

2. RCRA Case Study

Beyond the guidance the EPA provided, courts have added additional direction on applying RCRA to spent batteries, albeit not EV batteries directly. In *United States v. ILCO, Inc.*, the Eleventh Circuit considered "whether [the] EPA [had] reasonably construed the RCRA to permit regulation of the recycling of hazardous materials."¹⁰⁵ Specifically, on appeal, the EPA questioned whether reclaimed lead parts from automobile batteries for recycling purposes were exempt from RCRA.¹⁰⁶ The court recognized that the United States has experienced an increase in the number of spent batteries that have become

99. *Id.*

100. *Id.*

101. *Id.*; The California Energy Commission ("CEC") published several studies evaluating the need for recycling and the infrastructure required for successful LIB recycling. The CEC published a study titled "Direct Recycling Technology for Plug-In Electric Vehicle Lithium-Ion Battery Packs" and also publishes a report every two years titled the "Integrated Energy Policy Report." The CEC determined that direct recycling was the most cost effective and sustainable method to extract materials from LIBs. Neuhaus, *supra* note 28, at 85-86.

102. Boxerman & Langan, *supra* note 87.

103. *Id.*

104. In 2024, EV sales increased compared to the previous year, but the United States is experiencing a slowdown in the growth rate, which falls short of the 47% increase seen in 2023. Tom Krisher, *Despite Slowing Sales, Automakers are Expanding Electric Vehicle Models, Including Family Haulers*, THE SEATTLE TIMES (Nov. 20, 2024, 5:01 PM), <https://www.seattletimes.com/business/despite-slowing-sales-automakers-are-expanding-electric-vehicle-models-including-family-haulers/> [https://perma.cc/ZW7R-LDY5].

105. 996 F.2d 1126, 1130 (11th Cir. 1993).

106. *Id.*

useless and need disposal.¹⁰⁷ The court importantly noted that each unclaimed spent battery was a pollutant and a threat to human health.¹⁰⁸ The problem here was that the lead smelters that were open to reclaiming these batteries became a major environmental liability as well. The environmental problem was exacerbated when these smelters went out of business due to high regulatory compliance costs, and the smelters that remained open only reclaimed seventy percent of “[all the discarded batteries].”¹⁰⁹ The court understood the important role the smelter industry played in handling hazardous materials but found that the industry could not be exempt from regulation because its role in addressing environmental issues outweighed the harm caused by its operations.¹¹⁰

In this case, ILCO, a lead smelting facility, argued that the lead parts they reclaimed were not considered “solid waste” under RCRA and consequently not subject to RCRA because the lead parts were being recycled and were raw materials.¹¹¹ The court held that reclaimed lead parts from spent batteries are a solid waste and, therefore, are considered hazardous waste under RCRA.¹¹² The court reasoned that spent car batteries are considered hazardous waste when consumers discard them, and that it is irrelevant that the lead parts are not permanently discarded.¹¹³ Discarded solid waste that may be recycled is still solid waste.¹¹⁴ The court’s holding in *ILCO* may provide some guidance on proper disposal for future cases.

ILCO highlights a principle that can inform future regulatory decisions concerning EV LIB waste: materials that are discarded with the intent to be recycled may still fall under RCRA’s definition of hazardous waste; and when subject to RCRA, the EPA can regulate the battery waste from “cradle-to-grave.” While *ILCO* can be contrasted with EPA guidance that LIBs are not considered waste if they are being reused or repurposed, both frameworks are useful to determine how LIBs may be classified and regulated in the future.

B. European Union

1. EU Battery Directive

While the United States relies on RCRA to manage hazardous waste, the EU addresses similar challenges through a couple of regulatory frameworks. In response to the EU’s climate goals and achieving twenty-three percent of global EV sales by 2030, the EU promoted battery recycling through legislation called

107. *Id.* at 1128.

108. *Id.*

109. *Id.*

110. *Id.*

111. *Id.* at 1131-32.

112. *Id.*

113. *Id.* at 1132.

114. *Id.*

the “Battery Directive” (“Directive”).¹¹⁵ The Directive took effect on September 26, 2006, and sought to ban the sale of batteries that contain some hazardous substances, create a system to ensure high levels of collection and recycling, and establish fixed targets for these collecting and recycling activities.¹¹⁶

The Directive functions by applying EPR, placing the responsibility of recycling and disposal of spent LIBs back on producers and manufacturers.¹¹⁷ The Directive requires the use of battery passports, which inform consumers of the materials the batteries contain, where those materials came from, and their environmental impacts.¹¹⁸ Lastly, it also seeks to accomplish several other goals: mandate recycling efficiencies, material recovery rates, and target collection rates for recyclers, and create LIB reuse and remanufacturing standards.¹¹⁹

2. EU Batteries Regulation

The EU proposed an update to the EU Battery Directive called the EU Batteries Regulation (“Regulation”), which entered into force in 2023 and is expected to fully repeal the 2006 Battery Directive in 2025.¹²⁰ The European Commission proposed revising the previous Directive because of current “socioeconomic conditions, technological developments, markets, and battery uses.”¹²¹ The Regulation’s scope is broader than its predecessor and is being implemented in stages. Its first regulatory stage was implemented in February 2024, and its second in August 2024.¹²² Essentially, the 2006 Directive is being

115. Fricke, *supra* note 25, at 39; *2050 Long-Term Strategy*, *supra* note 24.

116. See Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC, 2006 O.J. (L 266); Hagan et al., *Annex - Comparative Analysis of Legal Frameworks*, WORLD ECON. F. at 11 (Dec. 2020), https://pacecircular.org/sites/default/files/2021-03/WEF_Annex_Comparative_Analysis_of_Legal_Frameworks_2020.pdf [https://perma.cc/AZG8-DVEF].

117. Stewart, *supra* note 45, at 151.

118. Robert Bird et al., *The Regulatory Environment for Lithium-Ion Battery Recycling*, 7 ACS ENERGY LETTERS 736, 738 (2022).

119. *Id.*

120. See Commission Regulation 2023/1542, 2023 O.J. (L 191); Marcus Navin-Jones & Oleksii Yuzko, *The EU Batteries Regulation: Taking Stock of the New EU Battery Requirements*, CROWELL (Sep. 11, 2024), <https://www.crowell.com/en/insights/client-alerts/the-eu-batteries-regulation-taking-stock-of-the-new-eu-battery-requirements> [https://perma.cc/6JH8-TWPC].

121. Directorate-General for Environment, *Circular Economy: New Law on More Sustainable, Circular and Safe Batteries Enters into Force*, EUR. COMM’N (Aug. 17, 2023), https://environment.ec.europa.eu/news/new-law-more-sustainable-circular-and-safe-batteries-enters-force-2023-08-17_en [https://perma.cc/GW82-M7Y2].

122. Roddy Martin et al., *EU Batteries Regulation: Next Implementation Stage Aims at Greater Transparency*, HERBERT SMITH FREEHILLS KRAMER (Sep. 16, 2024), <https://www.herbertsmithfreehills.com/insights/2024-09/EU-Batteries-Regulation--Next-implementation-stage-aims-at-greater-transparency-> [https://perma.cc/F5CN-7DHF]; Many of the legal requirements under the EU Batteries Regulation have not yet taken effect. The following are

phased out as the new Regulation is being phased in. The Regulation marks a significant turning point in the EU's regulation of batteries because it emphasizes a "strategic imperative" in achieving the EU's clean energy transition, moving beyond the primary focus of regulating solely for product safety.¹²³

Batteries coming from EVs fall within the scope of the Regulation if they are classified as "electric vehicle batteries"; batteries that do not comply with the Regulation cannot be sold on the market or enacted into service in the EU.¹²⁴ While the Regulation manages the manufacturing and sale of batteries, it also sets forth requirements on waste, disposal, recycling, and end-of-life issues.¹²⁵ Key requirements of the Regulation include battery passports, battery management systems, labeling, and EPR.¹²⁶ Recyclers will be required to provide reports on the recycling rates of materials extracted from the batteries and their recycling efficiency.¹²⁷

The United States falls behind the EU in regulation because the EU implements more prescriptive regulations and adopts different approaches addressing technologies for new policies, which may explain the United States' inadequate response to creating an effective battery recycling and disposal system.¹²⁸ The EU differs in that it embraces a precautionary approach, while the United States adopts a post-hoc regulatory approach.¹²⁹ This means that the EU seeks to proactively regulate risks, whereas the United States waits for evidence of actual harm before taking any steps to regulate.¹³⁰ This is likely due to the EU's "decentralized political system" versus the United States' federal system, which creates a "politically insulated process" for regulation, resulting in slow policy enactment and less responsiveness to consumers.¹³¹ The EU's decentralized system means that power is given to the individual member states to enforce the EU's regulations and policies, spreading power to multiple parties rather than concentrating power in a single authority.¹³² The United States is a

deadlines for additional stages to be implemented: "18 February 2025, 18 August 2025 (e.g. Due Diligence), 18 February 2027 (e.g. Battery Passport), 18 June 2028, 18 August 2028, 31 December 2028, 18 August 2031, 18 August 2036." Navin-Jones & Yuzko, *supra* note 120.

123. Navin-Jones & Yuzko, *supra* note 120; see *Proposal for a Regulation of the European Parliament and of the Council Concerning Batteries and Waste Batteries, Repealing Directive 2006/66/EC and Amending Regulation (EU) No 2019/1020*, at 1, COM (2020) 798 final (Dec. 10, 2020).

124. Navin-Jones & Yuzko, *supra* note 120.

125. *Id.*

126. For a more detailed list of other requirements in the EU Batteries Regulation, see *id.*

127. Meegoda, Malladi & Zayas, *supra* note 14, at 1169.

128. Neuhaus, *supra* note 28, at 88.

129. *Id.* at 88.

130. Jonathan B. Wiener & Michael D. Rogers, *Comparing Precaution in the United States and Europe*, 5 J. RISK RSCH. 317, 318 (2002).

131. Neuhaus, *supra* note 28, at 88.

132. *Introduction: The EU – A Political System, But Not a State*, CARLETON UNIV., <https://carleton.ca/ces/elearning/?p=404> [<https://perma.cc/3Y3X-GKM7>] (last visited Mar. 2, 2025).

constitution-based federal system in which power is distributed between the federal and state governments.¹³³ This federal system of government has drawbacks, particularly when conflicts arise between the federal and state governments over regulatory disagreements.¹³⁴

C. China

Like the EU, China has sought to embrace a leading role in adopting effective battery recycling practices to advance its goal of achieving a circular economy.¹³⁵ China has implemented plans and policies to address batteries, including China's Thirteenth Five-Year Plan, the Ministry of Ecology and Environment's "Policy on Technologies for Waste Batteries Pollution Prevention," and the 2020 "PRC Law on Prevention and Control of Environmental Pollution caused by Solid Wastes."¹³⁶ The Thirteenth Five-Year Plan seeks to improve the recycling industry for spent batteries and to "encourage the circular use of resources between production and society."¹³⁷ The "Policy on Technologies for Waste Batteries Pollution Prevention" provides guidance on spent batteries, including their collection, transportation, storage, maintenance, use, and reuse.¹³⁸ The PRC Law on Prevention and Control deals specifically with solid wastes, spent batteries included, by encouraging reuse and recycling.¹³⁹

Similar to the EU, China's regulatory approach for recycling and reuse of batteries rests primarily on EPR and regulates according to the type of battery classification.¹⁴⁰ Since EV sales have risen in China, Beijing has specifically enacted guidelines for spent battery recycling and placed responsibility for recycling on car manufacturers.¹⁴¹ Furthermore, China implemented the "Electric Vehicle Battery Recycling Technology Policy" in 2016, creating an EPR system that specified the responsibilities of producers to treat EV battery waste and develop aspects of treatment such as design, manufacturing, recycling, and reuse.¹⁴² Moreover, the "Promotion Plan for Extended Producer Responsibility System" in 2017 implemented an EPR system to regulate

133. *Federalism and the Constitution*, CONST. ANNOTATED, https://constitution.congress.gov/browse/essay/intro.7-3/ALDE_00000032/ [<https://perma.cc/5YRX-AWZB>] (last visited Mar. 2, 2025).

134. *Federalism*, EVERYTHINGPOLICY (Nov. 14, 2023), <https://www.everythingpolicy.org/policy-briefs/federalism> [<https://perma.cc/GA4K-LL7T>].

135. Hagan et al., *supra* note 116, at 16.

136. *Id.*

137. *Id.*

138. *Id.*

139. *Id.*

140. *Id.* at 17.

141. *Id.*

142. Wenbo Li et al., *Treatment of Electric Vehicle Battery Waste in China: A Review of Existing Policies*, 29 J. ENV'T ENG'G & LANDSCAPE MGMT. 111, 116 (2021).

LIBs.¹⁴³ Another distinct aspect of China's recycling programs is that vehicle manufacturers are required to attach a unique code to every battery produced or imported into China, which is shared with dismantling and recycling enterprises.¹⁴⁴ This helps further aid the tracking and proper recycling of spent batteries.¹⁴⁵ For every violation where a battery is not recycled properly, companies can expect a fine between ¥10,000 and ¥30,000.¹⁴⁶

Lastly, in 2018, China adopted the "Interim Measures for the Management of Recycling and Utilisation of Power Batteries of New Energy Vehicles" ("Interim Measures"), which consolidated some existing regulations and provided an overarching framework on EV battery waste treatment.¹⁴⁷ The Interim Measures seek to accomplish four goals: (1) make EV battery manufacturers responsible for end-of-life treatment, (2) encourage battery manufacturers to design easy-to-disassemble batteries and supply technical information about the batteries for end-of-life treatment to EV manufacturers, (3) promote reuse of waste batteries, and (4) place responsibility of progressing waste battery management standardization and implementation of a system regulating the waste process on the Ministry of Industry and Information Technology and other departments.¹⁴⁸

III. ANALYSIS

It is important to recognize that any meaningful discussion on solutions to environmental issues must also engage with policy considerations that help shape the legal atmosphere surrounding environmental law. The forthcoming analysis focuses on a policy argument, not with the intent to distract from legal discussion, but as a discussion necessary to illustrate that environmental law cannot exist without policy.

Chad McGuire offers a unique perspective on this and provides an illustration of how law is a piece of the puzzle for policy considerations.¹⁴⁹ For example, what might be a solution to address the issue of climate change? One policy option might be to prevent the release of carbon dioxide by prohibiting the uses of energy that release carbon emissions into the atmosphere, while another might be to mitigate carbon dioxide release through the integration of

143. Meegoda, Malladi & Zayas, *supra* note 14, at 1169.

144. Alexander Tankou, Georg Bieker & Dale Hall, *Scaling Up Reuse and Recycling of Electric Vehicle Batteries: Assessing Challenges and Policy Approaches*, INT'L COUNCIL ON CLEAN TRANSP., 1, 24 (Feb. 2023), <https://theicct.org/wp-content/uploads/2023/02/recycling-electric-vehicle-batteries-feb-23.pdf> [<https://perma.cc/7AKL-8QWU>].

145. *Id.*

146. *Id.* (10,000 Chinese yuan is equivalent to \$1,480 USD, and 30,000 Chinese yuan is equivalent to \$4,430 USD.)

147. Li et al., *supra* note 142, at 117.

148. *Id.*

149. CHAD J. MCGUIRE, ENVIRONMENTAL LAW FROM THE POLICY PERSPECTIVE: UNDERSTANDING HOW LEGAL FRAMEWORKS INFLUENCE ENVIRONMENTAL PROBLEM SOLVING 1 (Routledge 2014).

renewable energy portfolios.¹⁵⁰ A third option could focus on adaptation measures, but this route would emphasize dealing with climate change's effects rather than trying to address the cause of it.¹⁵¹

When solutions to climate change are considered, the context of how the law will impact these solutions and the law's ability to ensure the solutions' validity becomes important.¹⁵² In other words, when addressing environmental issues such as EV battery disposal, it is essential to evaluate the current laws and regulations to determine whether they promote or hinder the potential policy solutions. Once the solutions are generated, the law can then be examined to "help us determine its influence on our solution(s) to the problem."¹⁵³

For EV LIB disposal, one policy approach might be to require manufacturers to comply with recycling and disposal requirements through EPR. As argued in the ensuing analysis, this policy could be implemented by amending RCRA and establishing new recycling standards to promote a circular economy. Applying McGuire's approach, EV battery recycling solutions must be framed within policy decisions that can then be influenced and validated by the law. Establishing a foundation through a policy discussion is essential for addressing the legal environmental challenges for spent EV LIBs.

A. Extended Producer Responsibility

1. EPR Background

Although the United States is attempting to develop strategic practices for LIB recycling and reuse, it remains behind the EU and China, despite having high EV sales similar to those of both regions. Unlike the United States, the EU and China have implemented comprehensive EPR frameworks. These differing regulatory approaches between the jurisdictions can be partially blamed for this lag.

The foundation of EPR stems from two principles under international environmental law: the Principle of Pollution Prevention and the Polluter-Pays Principle.¹⁵⁴ The Principle of Pollution Prevention is commonly implemented in the environmental law sphere and suggests that environmental protection be achieved by taking a precautionary approach and preventing harm before it happens, instead of addressing the harm through remedies after it occurs.¹⁵⁵ On the other hand, the Polluter-Pays Principle requires those who pollute to

150. *Id.* at 2.

151. *Id.* at 3.

152. *Id.* at 4.

153. *Id.*

154. Tiptira Rammaniya, *Extended Producer Responsibility (EPR): An Alternative Solution to Regulate the International Electronic Waste Trade* 163-164 (Nov. 22, 2010) (S.J.D. dissertation, Golden Gate University) (on file with the Student Scholarship at GGU Law Digital Commons, Golden Gate University).

155. *Id.* at 165.

internalize their environmental externalities by taking responsibility for the social and environmental costs of their polluting activities.¹⁵⁶

Specifically, EPR “is a policy approach that requires manufacturers to finance the costs of collecting and recycling or safely disposing of products consumers no longer want,”¹⁵⁷ and can contribute to the establishment of a circular economy by increasing recycling and material recovery rates.¹⁵⁸ EPR is especially favored among municipalities because municipalities carry the burden of paying for waste management.¹⁵⁹ In addition to the benefits of saving the government money, implementing EPR can create an incentive for manufacturers to create products that are more durable and recyclable.¹⁶⁰

2. EPR in the United States

In the United States, states have implemented their own EPR policies, but EPR policies addressing the disposal of EV batteries have not been implemented at the federal level.¹⁶¹ While states have promulgated their own EPR policies, very few have implemented EPR policies focusing specifically on EV batteries. New Jersey is an exception and became the first state to implement an EPR policy for electric and hybrid vehicle batteries, enacting the Electric and Hybrid Vehicle Battery Management Act in January 2024.¹⁶² Taking effect in January 2027, the Act introduces EPR for EV batteries by placing the primary responsibility for recycling on the producers of batteries sold within the state.¹⁶³

156. Natalia Urzola et al., *State Responsibility for Disrupting Earth's Climate System: Anticipating the ICJ Advisory Opinion*, 55. ENV'T. L. REP. 10073, 10085 (2025); An environmental externality can either be positive or negative, and it is the result of a specific economic activity that affects a third party who is unrelated to the economic activity. Examples of a negative environmental externality include higher air pollution levels, degradation of land, and deforestation. Using the same examples, a positive environmental externality would be lower air pollution levels, rehabilitation of land, and reforestation. *What is an Externality?*, INT'L INST. FOR SUSTAINABLE DEV., <https://www.iisd.org/savi/faq/what-is-an-externality/> [<https://perma.cc/PD2P-RZDR>] (last visited Feb. 1, 2025).

157. Jennifer Nash & Christopher Bosso, *Extended Producer Responsibility in the United States: Full Speed Ahead?*, 2 (Harvard Kennedy School, Working Paper No. 10, 2013), https://www.hks.harvard.edu/sites/default/files/centers/mrcbg/files/Nash_Bosso_2013-10.pdf [<https://perma.cc/KR62-U6EK>].

158. *Circular Economy and Extended Producer Responsibility*, *supra* note 57, at 4.

159. Nash & Bosso, *supra* note 157, at 5.

160. *Id.*

161. *Id.* at 2.

162. S.B. 3723, 220th Gen. Assemb., Reg. Sess. (N.J. 2022-2023); *Recycle more batteries so they do less harm*, PROD. STEWARDSHIP INST., <https://productstewardship.us/products/batteries/> [<https://perma.cc/WR25-G897>] (last visited Feb. 2, 2025).

163. The Act has not fully been implemented. Starting January 2025, EV battery producers in New Jersey will be required to register with the New Jersey Department of Environmental Protection, and beginning January 2026, producers “must annually report to the DEP the quantity of EV batteries they sold, offered for sale, or distributed in New Jersey.” In January 2027, unauthorized persons will be prohibited from disposing EV batteries and its other components as

Additionally, the Act makes it illegal to dispose of EV batteries in landfills and mandates their reuse and recycling.¹⁶⁴ Other states, such as California and Washington State, as well as the District of Columbia, have enacted their own EPR battery policies, but New Jersey remains the only state to implement comprehensive EPR legislation for EV batteries.¹⁶⁵

Building on these state efforts, the EPA announced the agency's plan to implement EPR at the national level as required through the Bipartisan Infrastructure Law.¹⁶⁶ The scope of this EPR framework considers all battery chemistries and types, including lithium-based batteries and large batteries made for electric vehicles.¹⁶⁷ However, this framework is just in its beginning phases as the EPA is seeking input from experts to develop the national battery EPR framework.¹⁶⁸ The EPA recognizes the importance of having feedback from different industry groups and plans to seek input from battery producers, manufacturers, retailers, recyclers, collectors or processors, states and municipalities, and environmental, energy, or consumer organizations.¹⁶⁹

3. EPR in the European Union

The EU has begun its transition from regulating waste batteries under the 2006 Battery Directive to the revised regulation under the 2023 Batteries Regulation. The EU saw a need to revise its Directive “due to new socioeconomic conditions, technological developments, markets, and battery uses.”¹⁷⁰ Furthermore, the European Commission recognized the importance of providing “legal certainty” to players involved in the battery market, as batteries

solid waste, and solid waste facilities will be prohibited from knowingly accepting an EV battery for disposal, unless the facility has been given authorization from the state. Shennie Patel & Amanda Berman, *New Jersey Sets the Stage as the First State to Mandate Recycling of EV Batteries*, CROWELL (Feb. 14, 2024), <https://www.crowell.com/en/insights/client-alerts/new-jersey-sets-the-stage-as-the-first-state-to-mandate-recycling-of-ev-batteries> [https://perma.cc/G8T4-D76A].

164. *Id.*

165. *Id.*

166. *Extended Battery Producer Responsibility (EPR) Framework*, U.S. ENV'T PROT. AGENCY (Sep. 8, 2025), <https://www.epa.gov/infrastructure/extended-producer-responsibility-framework-batteries> [https://perma.cc/8WWL-DFEE]. The Bipartisan Infrastructure Law requires the EPA and the U.S. Department of Energy (“DOE”) to “develop a national EPR framework for batteries that addresses battery recycling goals, cost structures for mandatory recycling, reporting requirements, product design, collection models, and transportation of collected materials.” *Id.*

167. *Id.*

168. *Id.* (writing that the input includes discussion on covered batteries and products and potential exclusions; producer responsibilities and producer responsibility organization structure; federal, state, and local government roles and responsibilities; collection and recycling infrastructure; and product design).

169. *Battery Collection Best Practices*, U.S. ENV'T PROT. AGENCY (Aug. 22, 2025), <https://www.epa.gov/infrastructure/battery-collection-best-practices-and-battery-labeling-guidelines> [https://perma.cc/2YC3-J2EC].

170. Directorate-General for Environment, *supra* note 121.

are a key source of energy.¹⁷¹ To provide this legal certainty, the European Commission seeks to create a harmonized regulatory framework that addresses the entire life cycle of batteries that are placed on the EU market.¹⁷² The EU's framework can support the synergies of creating economic opportunities while addressing energy, climate, transport, and industry policies.¹⁷³

To understand the impacts of a battery waste management system and the potential effectiveness of the Regulation on the EU, it is important to consider the outcomes of the 2006 Directive and the foundation it provided for the newly amended, and yet to be fully implemented, Batteries Regulation. The European Commission assessed the Directive's successes and shortcomings by analyzing five elements: relevance, effectiveness, efficiency, coherence, and EU added value.¹⁷⁴

Relevance. The European Commission concluded that due to the rising use of batteries in the market, the presence of dangerous substances in batteries, and the number of spent batteries still not being properly treated, the Directive remains relevant.¹⁷⁵ The measures have achieved some success, such as reducing mercury and cadmium levels in batteries and increasing the collection and treatment of waste batteries. However, hazardous substances remain present in batteries, posing ongoing risks. Proper disposal is crucial to prevent environmental harm, but significant gaps in waste battery collection highlight that effective management remains a concern for the EU.¹⁷⁶ The Directive allows the member states to create their own national schemes, many of which are autonomous.¹⁷⁷ These schemes determine the success of the member states in meeting their collection rate targets. One of the Directive's key critiques was its insufficiency regarding material recovery.¹⁷⁸ While the Directive aimed to have high levels of material recovery through its collecting and recycling efforts, the Regulation did not adequately account for the growing significance of resource efficiency and circular economy policies.¹⁷⁹

Another criticism of the Directive was that lithium-based batteries were classified as "other batteries," which did not reflect the growing change and importance of battery use in "new 'transport' applications," such as electric

171. Commission Regulation 2023/1542, *supra* note 120, ¶ 2.

172. *Id.*

173. *Id.* ¶ 3.

174. *Commission Staff Working Document on the Evaluation of the Directive 2006/66/EC on Batteries and Accumulators and Waste Batteries and Accumulators and Repealing Directive 91/157/EEC*, at 28, SWD (2019) 1300 final (Apr. 9, 2019), https://ec.europa.eu/environment/pdf/waste/batteries/evaluation_report_batteries_directive.pdf [<https://perma.cc/WT9J-PYW9>] [hereinafter *Commission Staff Working Document*].

175. *Id.* at 30.

176. *Id.* at 31.

177. *Id.* at 55.

178. *Id.* at 32.

179. *Id.*; Stakeholders criticized the Directive in that its definition of recycling efficiency was not written to emphasize material recovery and that it failed to recognize high quality recycling as a priority. *Id.* at 33.

vehicles.¹⁸⁰ The issue with classifying lithium-based batteries as “other batteries” is that this category has only a recycling efficiency target of fifty percent.¹⁸¹ In other words, the recovery of lithium and other materials from these batteries was not guaranteed, which harmed efforts made to maximize the recovery of materials and align policies with circular economy goals. This issue was further aggravated by the Directive’s vague provisions on waste collection for industrial lithium batteries.¹⁸² The Directive categorizes industrial batteries as “exclusively designed for industrial or professional use or for use in any type of electric vehicle.”¹⁸³ So, while the *use* of the battery is classified as industrial, the lithium properties powering the battery classify it as “other batteries.” The Directive failed to set collection targets and mandatory reporting for lithium batteries, and the EPR policies addressing lithium batteries were weak compared to the EPR policies set for other types of batteries under the Directive.¹⁸⁴ The Battery Regulation recognized this shortfall and requires that EV batteries be specifically classified in their own category as “electric vehicle batteries.”¹⁸⁵

Finally, stakeholders believe that the Directive lacked a clear legal framework for the development of the second life of batteries.¹⁸⁶ For LIBs from EVs, the term “second life” means “a new nonautomotive use of an automotive LIB after its initial use in a vehicle.”¹⁸⁷ Due to the large capacity of LIBs in EVs, batteries often have storage capacity leftover when the battery can no longer be used to meet the energy demands the EV requires. Because of this, the battery’s remaining capacity can be repurposed for other opportunities.¹⁸⁸ The Directive did not consider second-life batteries because current legislation was unable to integrate them into the Directive.¹⁸⁹

Due to the previously mentioned reasons, and since environmental concerns will still exist from the increase in battery usage, the Directive’s objectives remain relevant. Accordingly, the 2023 Battery Regulation can hopefully address some of these concerns where the Directive fell behind.

Effectiveness. The European Commission reported that the Directive has been able to decrease batteries’ environmental impact by reducing the hazardous materials used in batteries and preventing waste portable batteries from ending up in landfills or incineration facilities.¹⁹⁰ Unfortunately, the huge misstep in the

180. *Id.* at 33-34.

181. *Id.* at 34.

182. *Id.*

183. *Id.* at 5.

184. *Id.* at 34.

185. Navin-Jones & Yuzko, *supra* note 120.

186. *Commission Staff Working Document*, *supra* note 174, at 34.

187. U.S. DEP’T OF ENERGY, BATTERY SECOND LIFE FREQUENTLY ASKED QUESTIONS (2020), https://afdc.energy.gov/files/u/publication/battery_second_life_faq.pdf [<https://perma.cc/XN6H-C4KC>].

188. *Id.* (noting that an LIB could still have 80% of its usable energy capacity at the end of its life).

189. *Commission Staff Working Document*, *supra* note 174, at 34.

190. *Id.* at 69.

Directive's monitoring collection rates of batteries is that it failed to require reporting obligations for automotive and industrial batteries, making it difficult to see a full and accurate set of data to determine what happened to all waste batteries.¹⁹¹ The root problem was limiting the collection targets to portable batteries only, ultimately contradicting the Directive's goal of applying to all types of batteries.¹⁹² However, parties involved with the SET action plan seek to achieve a goal of collecting seventy percent of lithium batteries by 2030.¹⁹³ Despite the EU's data collection limitations, the Commission reported success on some of its initiatives when member states met the Directive's recycling efficiency goals, along with reports showing a significant increase in recycled batteries and improved environmental performance.¹⁹⁴

Stakeholders reported that labeling requirements failed to effectively inform users of the batteries' characteristics, the risks of using them, and the need to collect and recycle them once they are spent.¹⁹⁵ The Directive should have included labeling provisions informing users of hazardous substances and the risks of lithium batteries, specifically.¹⁹⁶ To address this issue, the Regulation suggests implementing labeling practices for batteries to "provide end-users with transparent, reliable and clear information about batteries and waste batteries."¹⁹⁷ This labeling information will assist end-users in making informed choices when purchasing and disposing of batteries, and also help waste operators treat the waste batteries.¹⁹⁸ The labels will include key information, including the batteries' characteristics, such as their capacity and the hazardous substances present in the battery.¹⁹⁹

Efficiency. Stakeholders shared that the Directive has caused businesses to incur significant costs, but admitted that the costs are justified given that the Directive not only produced current and future benefits, but also brought market opportunities.²⁰⁰ For lithium batteries specifically, the costs of collecting, treating, and recycling the batteries often offset the revenue generated from selling the recovered materials from these batteries. Recyclers argue that, because there is a lack of a recycling efficiency target and an obligation to recover the metals, incentives are reduced to ensure efficient recovery.²⁰¹ Consequently, it is the producers who bear responsibility for covering the extra

191. *Id.* at 36.

192. *Id.* at 38.

193. *Id.*; Implemented in 2007, the SET plan seeks to advance the EU's energy and climate goals while positioning Europe as "a global leader in low-carbon energy and energy efficiency technology." *SET Plan in Action*, EUR. COMM'N, https://setis.ec.europa.eu/about-set-plan/set-plan-action_en [<https://perma.cc/8642-G8P3>] (last visited Feb. 8, 2025).

194. *Commission Staff Working Document*, *supra* note 174, at 39-41.

195. *Id.* at 44.

196. *Id.*

197. Commission Regulation 2023/1542, *supra* note 120, ¶ 44.

198. *Id.*

199. *Id.*

200. *Commission Staff Working Document*, *supra* note 174, at 49.

201. *Id.* at 50.

costs through their recycling fees.²⁰² The Regulation addresses this issue by implementing targets for recycling efficiency and recovery of materials for lithium-based batteries.²⁰³

The Commission stated that setting clear and reliable targets for lithium recycling would significantly enhance recycling efforts. If these recycling targets are set for lithium batteries, the Commission anticipates that these efforts can decrease the demand needed for lithium and cobalt to manufacture EVs in the EU.²⁰⁴ An increase in recycling could provide a significant portion of “secondary lithium for EV batteries from 2050.”²⁰⁵ Notably, a decrease in demand for lithium and cobalt could also positively affect the environment, as it could mitigate harm from mining activities. The Battery Regulation, fortunately, seeks to address this gap. The Regulation recognizes that effectively using recovered raw materials would not only support the goal of achieving a circular economy but also help the EU reduce its dependency on purchasing raw materials from outside nations.²⁰⁶ The Regulation therefore seeks to establish mandatory recycled content targets for lithium by 2031, with plans to raise these targets by 2036.²⁰⁷ Furthermore, the recycling rate for lithium is expected to increase from thirty-five to seventy percent between 2026 and 2030.²⁰⁸

The Directive faces efficiency challenges due to inconsistent enforcement among the member states. These enforcement gaps place producers who strictly comply with the Directive at a disadvantage compared to those engaging in less compliant practices, because the sub-standard practices and different levels of recycling among EU nations may cause unfair competition.²⁰⁹ This creates an uneven playing field for producers who face higher compliance costs, whereas less compliant producers avoid these costs. Another issue is that calculations for recycling efficiencies are distorted because of the lack of EU-wide criteria for determining when recycled battery parts, such as the lead and plastics of batteries, cease to be classified as waste.²¹⁰ To address these concerns, stakeholders believe that creating a certification system for recycling plants would ensure uniform standards for battery recycling across all EU countries.²¹¹ Most public consultation respondents agreed the current and future benefits of the Directive outweighed the costs associated with its implementation,²¹² and

202. *Id.*

203. Commission Regulation 2023/1542, *supra* note 120, ¶ 115.

204. *Commission Staff Working Document*, *supra* note 174, at 51.

205. *Id.*

206. Commission Regulation 2023/1542, *supra* note 120, ¶ 30.

207. *Id.*

208. Meegoda, Malladi & Zayas, *supra* note 14, at 1169.

209. *Commission Staff Working Document*, *supra* note 174, at 57.

210. *Id.* at 57-58.

211. *Id.* at 58.

212. *Id.* at 54.

further agreed the Directive was not suitable for handling the anticipated rise in industrial batteries.²¹³

Batteries used in the transport sector will see a sharp increase in the number placed on the market; however, a major drawback of the Directive was that responsibility for returning spent industrial batteries was placed on the end-user, leaving some to question whether this responsibility was suitable when it came to returning large batteries.²¹⁴ Moreover, the Commission notes that the relevant provisions for introducing industrial batteries onto the market and for managing battery waste are too ambiguous to provide enough guidance for enforcing EPR principles.²¹⁵

Coherence and internal consistency. The Commission considered the overlap and interactions of the Directive with other EU policies. The Commission briefly discussed the Directive's relationship with the Waste Framework Directive ("WFD"), REACH ("Registration, Evaluation, Authorization, and Restriction of Chemicals"), and RoHS ("Restriction of Hazardous Substances"), concluding that the policies are complementary, nonduplicative, and mutually exclusive in managing hazardous substances, respectively.²¹⁶ The Directive has some overlap with the Directive on the Management of Waste Electric and Electronic Equipment ("WEEE"), which has caused concerns with non-harmonious definitions between the two policies. For example, the Directive and WEEE's definition of "producer" are different.²¹⁷ Inconsistencies between the Directive and other EU policies can lead to misreporting issues and concerns with proper classification for battery treatment.²¹⁸

Criticism of the Directive's internal consistency surrounds its failure to properly present long-term goals and objectives, and it lacks specific targets for some of these goals, preventing the ability to assess compliance with the Directive.²¹⁹

EU Added Value. The Directive is recognized for its benefits, particularly its role in protecting human health and the environment.²²⁰ It has also prompted member states to adopt legal provisions on batteries and integrate EPR into their frameworks.²²¹

Moving beyond the Commission's analysis of the five elements previously discussed, the Directive recognizes and incorporates the Polluter Pays Principle, imposing responsibilities on the producers to integrate EPR principles into their

213. *Id.* at 58.

214. *Id.*

215. *Id.* at 59.

216. *Id.* at 60.

217. *Id.* at 61.

218. *Id.* at 61-62.

219. *Id.* at 65.

220. *Id.*

221. *Id.*

management practices for the end-of-life batteries.²²² Producers will be obligated to pay for collection costs, treatment of batteries, recycling, reports on batteries and waste batteries, and inform end-users and waste operators about proper re-use and management of waste batteries.²²³ The new EPR rules under the Regulation aim to achieve high levels of protection for the environment and human health by optimizing the separate collection of waste batteries and ensuring that the collected batteries are recycled through processes that achieve both high recycling efficiency and material recovery, in accordance with current technical and scientific progress.²²⁴

Although the full impact of the Regulation remains unclear, since its implementation is still in progress, its refinement and expansion from the Directive will not only serve as a major milestone for the protection of human health and the environment, but also holds the potential to serve as a valuable blueprint for other nations.

4. EPR in China

EVs are also emerging in China, and like the EU and the United States, China is not immune to the environmental effects of battery pollution. While a comprehensive evaluation of China's battery waste management systems and EPR framework is limited compared to the extensive analysis provided by the EU, there are still valuable studies that highlight the successes of EPR in managing EV battery waste in China. These studies emphasize the role of EPR in advancing sustainable practices, improving recycling efficiency, and fostering green technological innovation in the EV battery sector. Additionally, the United States can learn from China's approach by analyzing the successes and challenges of its EPR system and using these insights to inform the development of a national battery recycling program.

Due to the rapid rise in EVs in China, companies may produce "immature technologies" to prioritize their short-term profit.²²⁵ The production of immature technologies, coupled with incomplete recycling management programs, can lead to significant metal waste and contribute to environmental pollution.²²⁶ China's policies, including the Plan for Extended Producer Responsibility, place responsibility for recycling battery waste on enterprises involved in battery

222. Commission Regulation 2023/1542, *supra* note 120, ¶ 101. The Regulation defines producer as "any manufacturer, importer or distributor who, irrespective of the selling technique used . . . supplies a battery for the first time for distribution or use, including when incorporated into appliances, light means of transport or other vehicles, within the territory of a member state on a commercial basis." *Id.* ¶ 100.

223. *Id.* ¶ 101.

224. *Id.*

225. Cailou Jiang & Yue Zhang, *Does Extended Producer Responsibility System Promote Green Technological Innovation in China's Power Battery Enterprises?*, SUSTAINABILITY 1, 1-2 (Aug. 12, 2023).

226. *Id.* at 2.

production.²²⁷ To address recycling costs and mitigate the pollution issues arising from a battery's life cycle, these companies participate in "green technological innovation" to enhance efficient use of raw materials, including lithium.²²⁸

Imposing recycling responsibility on the producer is done through external measures, which encourage the movement away from traditional cost-driven production models and encourage businesses to strengthen their pollution control technology and recycling methods.²²⁹ Additionally, government subsidies play a crucial role in promoting green technological innovation among battery producers by providing financial incentives, which further encourage these producers to adopt practices that promote pollution control and recycling.²³⁰ EPR also promotes these practices through consumers' prioritization of environmentally friendly products, pushing companies to adopt green innovation measures to avoid the outside pressure of failing to meet regulatory expectations.²³¹

Despite researching a small sample size, Cailou Jiang and Yue Zhang concluded that the EPR system in China has advanced the green innovation of battery producers, resulting in an increase in high-quality green invention patents.²³² The study indicated that the EPR system fosters green innovation through enhanced government subsidies and increased awareness of environmental sustainability by company executives.²³³

Another study further considered China's policies on management for spent EV batteries and discussed several shortcomings of the policies addressing battery waste: (1) lack of provisions for historical and orphan batteries, (2) no target on battery collection, (3) unclear definition of the scope of authority, (4) inadequate regulatory standards for data auditing and verification, (5) uncooperative stakeholders, (6) and lack of specificity on financing mechanisms.²³⁴

China's policies lack guidance on whether or not China considers historical and orphan batteries in its waste management framework. Historical batteries are "waste batteries from EVs that have been sold prior to the implementation of the current policy framework," and orphan batteries are "waste batteries from EVs whose manufacturers have ceased to exist."²³⁵ The significance of addressing historical and orphan battery issues is highlighted by China's experience of declining EV sales in 2019 due to reduced government subsidies

227. *Id.*

228. *Id.*

229. *Id.* at 13.

230. *Id.*

231. *Id.*

232. *Id.*; Green invention patents are essentially patents for technologies related to resource conservation and clean production. Cailou Jiang and Yue Zhang assessed the quality of patents as it relates to alternative energy, transportation, energy conservation, and waste management. *Id.* at 6.

233. *Id.* at 13-14.

234. Li et al., *supra* note 142, at 118-19.

235. *Id.* at 118.

and the impact of the COVID-19 pandemic.²³⁶ A drop in sales means EV manufacturers will struggle to stay afloat, which could pose an issue for effective battery management if these producers were to go bankrupt. Bankruptcy results in the manufacturers' batteries becoming orphan products, making the EPR framework difficult to implement when spent batteries cannot be sent back to their original manufacturer.²³⁷ Another concern is the lack of targets for battery collection. China's battery framework only sets targets focusing on material recovery from EV batteries during the recycling process and fails to set targets for the overall collection of these batteries.²³⁸ In other words, while China has importantly set recovery goals for lithium, for example, the lack of overall collection means fewer batteries are being brought into the waste stream for proper recycling and disposal.²³⁹

The failure to have a clear definition for the scope of authority is another issue presented by China's regulatory framework. Managing EV battery waste in China is challenging due to the dominance of an informal recycling sector. Unqualified recyclers are often able to offer high bids to EV users for their spent batteries because they do not have to pay environmental and safety compliance costs associated with recycling.²⁴⁰ EV users are then misled about their battery's remaining value and recycle the battery with these unqualified recyclers, leading to issues where fewer qualified waste recyclers are treating EV batteries. The Chinese government has taken action by introducing regulatory standards for waste battery treatment, but the success of this measure depends on its effective administration and enforcement, a responsibility shared between central and local agencies.²⁴¹ There is a lack of clear authority between these agencies, which not only results in poor administration and enforcement but also leads to EV subsidy fraud by large EV makers due to weak auditing and oversight.²⁴²

Additionally, China has implemented a traceability management system for battery manufacturers, EV makers, car dealers, and reuse and recycling companies to record and update battery information for the battery's life cycle from production to disposal.²⁴³ However, the Interim Measures govern this system, which is a problem for effective data collection because they lack defined requirements for data auditing and verification.²⁴⁴

Uncooperative stakeholders also present a significant challenge for the implementation of China's battery policies. While Cailou Jiang and Yue Zhang have noted that the EPR system has improved the sustainability of pollution

236. *Id.*

237. *Id.*

238. *Id.*

239. *See id.*

240. *Id.*

241. *Id.*

242. *Id.* at 118-19.

243. *Id.* at 119.

244. *Id.*; *see supra* Section II.C. (discussing China's Interim Measures and the four goals the Interim Measures seeks to achieve for EV battery recycling).

control technology and recycling methods in China, EPR's success relies on the support of stakeholders involved in the collection, recycling, and disposal processes.²⁴⁵ Without this cooperation, manufacturers face significant obstacles in effectively taking back used batteries, undermining the goals of the EPR system and limiting its overall impact.

Lastly, China's policies addressing battery waste lack specificity regarding financing mechanisms. Incentives for EV battery recycling are often limited due to technological immaturity, a small reused battery market from high battery refurbishment costs and lower new battery costs, and poor economic viability.²⁴⁶ The current framework for treating used batteries lacks explicit financing mechanisms, leaving producers to develop their own mechanisms for treating waste batteries.²⁴⁷ This is problematic, however, since developing unilateral policies can lead to ineffective cost recovery for producers, a problem that is only exacerbated for EV producers who are seeing declines in their EV sales.²⁴⁸

*B. A Comparative Analysis of EPR Systems in the EU & China,
to the United States*

Admittedly, the different physical, social, and political landscapes between the EU, China, and the United States determine the policies that will be implemented and how these policies will take effect.²⁴⁹ These differentiating factors often mean that environmental problems are viewed differently in each jurisdiction. Importantly, the United States' historical frameworks of individualism and capitalism often limit the policies and laws the government can implement, and the attempts to fully enact EPR at a national level have been no exception.²⁵⁰ Limitations of EPR at the national level are also a result of company concerns surrounding lawsuits in the United States, specifically worrying about the liability that may be incurred from taking back products with hazardous materials.²⁵¹ Consumers are also the ones who end up paying for waste management of end-of-life products through internalized costs in the products' price increases.²⁵²

The United States' efforts to implement federal EPR policies have been unsuccessful. In 1992, although not specifically related to EV battery management, there was an attempt to introduce provisions related to EPR

245. Li et al., *supra* note 142, at 119.

246. *Id.*

247. *Id.*

248. *Id.*

249. Bette K. Fishbein, *Part II: The EPR Policy Challenge for the United States*, in EXTENDED PRODUCER RESPONSIBILITY: A MATERIALS POLICY FOR THE 21ST CENTURY 1, 55 (INFORM, Inc. 2000).

250. *Id.* at 56.

251. *Id.*

252. *Id.* at 62.

packaging into the RCRA reauthorization bill.²⁵³ This attempt failed, curbing the efforts to enact EPR legislation at the federal level and further creating a hostile political climate surrounding federal EPR legislation.

The United States' efforts to implement successful EPR policies for effective EV battery waste management continue to fall short of the regulations enacted by the EU and China. The EU and China's comprehensive frameworks have established clear responsibilities for producers, set ambitious recycling targets, and integrated circular economy principles into their frameworks. In contrast, the United States not only lacks a comprehensive regulatory framework for EPR battery management but also fails to implement any regulation at all at the national level. This leaves battery waste management to be inconsistently addressed at the state level, creating fragmented policies, limiting enforcement mechanisms, and limiting recycling efforts in the few states with waste policies compared to the broader impact that could be achieved through federal implementation.

For the few states that have either implemented an EPR battery regulation or are attempting to introduce legislation, their efforts provide an opportunity to examine how these state initiatives compare with the regulations seen by the EU and China. As the first state to implement a policy on EPR EV battery waste, New Jersey's Electric and Hybrid Vehicle Management Act framework is worth analyzing. First, the Act requires each producer to develop its own management plan detailing its recycling system once the New Jersey Department of Environmental Protection finalizes the framework for the entire recycling process for EV battery producers.²⁵⁴ New Jersey's Act shares some similarities with the EU's approach in that it provides overarching regulatory requirements while allowing producers the flexibility to enact their own management plans, subject to state approval. This is compared to the EU's approach, where its legal framework sets rules and objectives, but allows the implementation of the framework to be left to each individual member state. It will be interesting to see if New Jersey's reliance on individualized management plans becomes problematic in the future, as variations between producers' plans could lead to inconsistencies during implementation if each producer develops a different approach to its recycling system.

Second, New Jersey's Act is comparable to the EU and China because the Act sets standards and criteria for EV batteries' entire recycling process, including collecting, transporting, recycling, reusing, repurposing, and disposing.²⁵⁵ This approach aligns with the principles of a circular economy, ensuring that batteries are not just properly disposed of but also recycled and reused to minimize waste and mitigate environmental impacts.

Thus, while New Jersey's Act shares some similarities regarding frameworks, goals, and concerns, New Jersey's model only works in isolation with no federal

253. *Id.* at 73.

254. Patel & Berman, *supra* note 163.

255. *Id.*

regulation or overarching guidance, unlike the EU and China. Though limited, New Jersey can still provide a blueprint for other states to follow. California, for example, attempted to pass SB 615, which focused on EPR for EV batteries, under which suppliers would be responsible for the collection and management of EV batteries at the end of their life.²⁵⁶ The bill proposed a “battery management hierarchy” that would prioritize reuse, repair, and remanufacture, while also requiring unique identifiers for each battery to enable responsible tracking.²⁵⁷ Surprisingly, given California’s quite progressive nature on environmental matters, SB 615 did not pass, as it was vetoed by Governor Gavin Newsom. Governor Newsom justified his veto by explaining that rather than expanding on the effectiveness of current EPR models, SB 615 would impose a significant burden on the Department of Toxic Substances Control to implement the policy.²⁵⁸

Even implementing EPR at the state level is proving to be difficult. While efforts are still underway, state-level efforts may continue to struggle without a comprehensive, uniform federal framework for states to follow.

C. Consequences of Failing to Devise a National EPR Program

Aside from the obvious environmental consequences if the United States does not implement an EPR framework for EV battery recycling programs, the United States will continue to be viewed as lagging behind in environmental policy leadership.²⁵⁹ Rather than being a leader in environmental policy, the United States has fallen behind other developed-world nations,²⁶⁰ as is especially evident by the current discussion surrounding the United States lagging behind the EU and China concerning EV battery waste management plans. However, through the United States’ government and businesses embracing sustainable initiatives, such as supporting and implementing an EPR battery waste framework, the United States will have the potential to be seen as a leader in taking positive environmental initiatives. Additionally, not only will the United States benefit from sustainable initiatives taken by businesses, but businesses themselves can expect to see improved reputations, competitive

256. *EPR Bills on California Governor’s Desk Reflect Strong and Growing Movement*, PROD. STEWARDSHIP INST. (Sep. 5, 2024), <https://productstewardship.us/epr-bills-on-california-governors-desk-reflect-strong-and-growing-movement/> [<https://perma.cc/7BLZ-9FM9>].

257. *Id.*

258. Letter from Gavin Newsom, Governor of the State of Cal., to Members of the California State Senate (Sep. 29, 2024) (on file with the Office of the Governor).

259. See Jason Scorse, *Why the U.S. is No Longer a Leader in Environmental Policy*, PROGRESSIVE POL’Y INST. (Apr. 22, 2011), <https://www.progressivepolicy.org/why-the-u-s-is-no-longer-a-leader-in-environmental-policy/> [<https://perma.cc/7H58-M6AF>]; see also *Perceptions of U.S. Environmental Policy Lag Behind Many Other Countries*, UNIV. OF MOUNT SAINT VINCENT (Mar. 7, 2018), <https://mountsaintvincent.edu/perceptions-of-u-s-environmental-policy-lag-behind-many-other-countries/> [<https://perma.cc/258N-HD2P>].

260. Scorse, *supra* note 259.

advantages, receive government incentives, be viewed as leaders in innovation, and be ahead of compliance regulations.²⁶¹

D. EPR—The Right Approach?

Implementing an EPR framework may not only be a turnoff due to its complexity, but also the costs still remain a concern in the transition toward an EPR approach.²⁶² Determining the costs of design, manufacturing, marketing, extraction, and recycling, and who should bear these costs, is difficult to assess.²⁶³ In some cases, the costs to take back the materials and recycle them could exceed the initial costs of extracting the materials.²⁶⁴ The concern is that EPR will raise product costs because producers would be inclined to pass these recycling costs on to consumers. However, there has been no credible evidence that consumers will bear the costs associated with implementing EPR.²⁶⁵ A Columbia University paper argued that the biggest driver of prices is due to supply and demand, and that this elasticity plays an important role in the pricing.²⁶⁶ Other factors, such as commodity prices, energy costs, transportation costs, and inflation, also affect product prices.²⁶⁷ Essentially, there are too many factors affecting product prices, and it is difficult to argue that EPR alone would cause prices to increase. Blaming price increases on EPR “would be like saying that a rock thrown into an ocean could cause a tsunami.”²⁶⁸

Another concern with EPR laws is that this principle does not address levels of consumption.²⁶⁹ EPR can promote sustainable design, reuse, and recycling, but it has no effect on the number of products consumed.²⁷⁰ This concern could be applicable to battery waste management, as the previously mentioned EU and Chinese policies do not directly address battery consumption levels. EPR for batteries can, of course, address the design, reuse, and recycling of the products, but it seems the policies do not have a significant impact on the number of batteries produced and consumed. In other words, even with EPR enacted, the demand for batteries will rise as demand for EVs increases. With EPR focusing mostly on producers taking back batteries for proper disposal and recycling, the framework addresses end-of-life management issues. In essence, the EPR

261. *Why Are Green Initiatives Suddenly So Important for Your Business?*, OCTOPUS ELEC. VEHICLES (Nov. 12, 2024), <https://octopusev.com/ev-hub/the-importance-of-green-initiatives> [https://perma.cc/N44N-57DS].

262. Rammaniya, *supra* note 154, at 197, 200.

263. *Id.* at 200.

264. *Id.* at 200-01.

265. Michael Washburn, *Blog: Does EPR Increase Consumer Costs? Spoiler Alert – Not as Much as Critics Say*, THE RECYCLING P'SHIP (Aug. 1, 2022), <https://recyclingpartnership.org/economicresearch/> [https://perma.cc/T5WZ-2K78].

266. *Id.*

267. *Id.*

268. *Id.*

269. James Salzman, *Sustainable Consumption and the Law*, 27 ENV'T L. 1243, 1280 (1997).

270. *Id.*

principle appears more reactive in nature, focusing on managing batteries only after they have been used and completed their life cycle. As mentioned in previous sections, however, ideally, the EPR framework would create effective reuse and recycling programs, which would decrease the demand for new batteries and the need for heightened mining extraction of raw materials.

Despite the United States having a relatively hostile view of EPR mandates, perhaps it could gain favor among stakeholders involved throughout the battery management process. Moreover, although EU stakeholders considered costs an issue, many agreed that the Directive's costs were justified given the current and future benefits and market opportunities.²⁷¹

IV. RECOMMENDATIONS

The United States should follow in the footsteps of the EU and China and implement federal EPR legislation for EV batteries that addresses the full life cycle of the batteries, including reuse and recycling. To do this, Congress should amend RCRA to address the emerging issue of increased EV battery waste. RCRA could provide a legal foundation to bring these policy solutions to fruition. RCRA has been amended in the past to address environmental challenges, and similar amendments can incorporate provisions for EPR policies focused on end-of-life battery management for EVs.²⁷² Specifically, RCRA's amendments include the Hazardous and Solid Waste Amendments of 1984, Federal Facility Compliance Act of 1992, and Land Disposal Program Flexibility Act of 1996.²⁷³ The following are recommendations on steps the United States should take to address the spent battery problem.

First, rather than rely only on the EPA's guidance memo establishing LIBs as hazardous waste, EV LIBs should be explicitly categorized under RCRA as hazardous waste. Since RCRA gives the EPA the authority to regulate hazardous waste from "cradle to grave," this would grant the EPA authority over the battery's entire life cycle.²⁷⁴ Second, RCRA should be amended to integrate provisions based on the EPR principle for EV batteries. Similar to the requirements under the EU and China's frameworks, the provisions should

271. *Commission Staff Working*, *supra* note 174, at 49.

272. *See History of the Resource Conservation and Recovery Act (RCRA)*, U.S. ENV'T PROT. AGENCY (Feb. 11, 2025), <https://www.epa.gov/rcra/history-resource-conservation-and-recovery-act-rcra> [<https://perma.cc/GF7C-KAFJ>].

273. *Id.*; The Hazardous and Solid Waste Amendments of 1984 made substantial additions to RCRA by expanding the "coverage and requirements for hazardous industrial waste." The Federal Facility Compliance Act of 1992 "strengthened enforcement of RCRA at Federal facilities," and the Land Disposal Flexibility Act of 1996 "provided regulatory flexibility for land disposal of certain wastes." *The History of the Resource Conservation and Recovery Act*, DANIELS TRAINING SERVS. (Feb. 11, 2013), <https://danielstraining.com/the-history-of-the-resource-conservation-and-recovery-act/> [<https://perma.cc/GYD6-F63R>].

274. *Summary of the Resource Conservation and Recovery Act*, U.S. ENV'T PROT. AGENCY (July 31, 2024), <https://www.epa.gov/laws-regulations/summary-resource-conservation-and-recovery-act> [<https://perma.cc/X4HL-VY2X>].

outline the obligations of battery producers, such as establishing take-back programs, financing collection, and meeting specific recycling rates. Additionally, new provisions should give the EPA authority to establish a national framework modeled after the EU's harmonized approach. The provisions should include setting consistent collection targets, requiring producers to report to the EPA the quantity of batteries collected and recycled, and ensuring uniform compliance standards nationwide. A strict EPR take-back policy, however, that provides producers with little to no incentive to reuse or recycle their batteries will have no effect on fixing the battery problem.²⁷⁵ Therefore, the government should provide incentives through tax deductions or credits for the products they take back.²⁷⁶

Here, RCRA provides a strong foundation for identifying and regulating hazardous waste, including spent batteries. However, RCRA alone cannot provide the solution to the challenges the United States will face regarding battery waste management. This is where EPR becomes vital to integrate into federal law: EPR can build upon the foundation laid by RCRA by shifting the responsibility of managing this waste onto producers. An attempt to establish harmony between RCRA and the EPR framework can ensure compliance with current waste standards while developing the much-needed solution of sustainable recycling and proper disposal.

While the EU and China provide valuable frameworks for managing EV battery waste, the United States should remain aware of the shortcomings of these approaches. By assessing the limitations of these frameworks, the United States can craft laws that prioritize effective and efficient battery management while tailoring solutions to its social, political, and economic landscape. Despite these valuable frameworks, a key challenge in using the EU and China's frameworks to inform the United States' approach is the absence of standardized definitions, data, and reporting mechanisms.²⁷⁷ For example, terms such as "waste" and "recycling" can have different meanings across nations.²⁷⁸

Even though the United States has resisted EPR mandates, EPR remains an internationally used framework and "the success or failure of EPR programs abroad will undoubtedly influence future policy in the [United States]."²⁷⁹ However, it is crucial to recognize that nations may interpret successes and failures differently, depending on the specific goals of each program and country implementing it.²⁸⁰

275. Betsy M. Billinghurst, *E-Waste: A Comparative Analysis of Current and Contemplated Management Efforts by the European Union and The United States*, 16 COLO. J. INT'L ENV'T L. & POL'Y 399, 426 (2005).

276. *Id.* at 427.

277. FISHBEIN, *supra* note 249, at 105.

278. *Id.* at 106.

279. *Id.*

280. *Id.*

V. CONCLUSION

As a top seller of EVs, the United States can expect an increase in spent battery waste in the coming years. Therefore, it is key to implement solutions to mitigate the environmental and human health impacts of waste. Although EV sales have risen over the past several years, the United States lags significantly behind the EU and China, despite these jurisdictions also seeing a rise in EV sales. The United States will benefit from implementing EPR principles into its regulatory framework through legislation by amending RCRA. Specifically, the United States needs to implement federal legislation that places responsibility for battery reuse and recycling back on producers to promote sustainable battery products and manufacturing processes and push the nation towards a circular economy model. The United States should consider the EU and China's frameworks to inform its approaches and learn from their policy shortcomings to enact effective policies for battery waste management. The United States has the opportunity to improve its battery recycling landscape, and it must take it. The decisions made now will define the trajectory of battery waste management for years to come, and with legislative action, the United States can turn its inevitable battery crisis into an opportunity for international leadership. The United States must leave behind its historical resistance to a national EPR approach and adopt a uniform, comprehensive battery waste regulation. In the words of George Bernard Shaw, "[p]rogress is impossible without change, and those who cannot change their minds cannot change anything."²⁸¹

281. *Progress Is Impossible Without Change*, THRIVE GLOB. (Sep. 5, 2018), <https://community.thriveglobal.com/progress-is-impossible-without-change/> [https://perma.cc/LJM6-8APA].